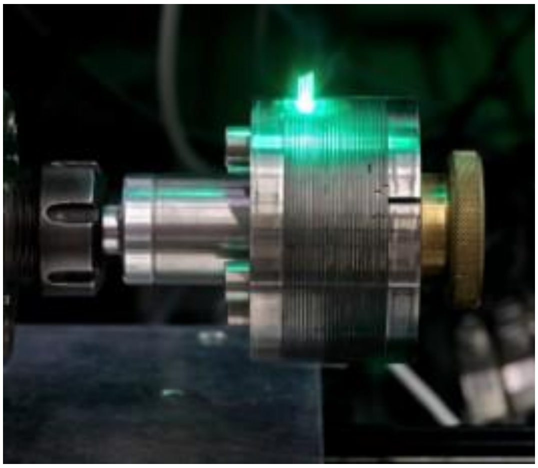
METAMORPHA newsletter Sep-2023 (#2)

Made-to-measure micromachining with laser beams tailored in amplitude and phase

Welcome to the September 2023 METAMORPHA project newsletter!



Progress in METAMORPHA has been very encouraging in the first year of the project. In this newsletter we can report on advances made in four different project areas:

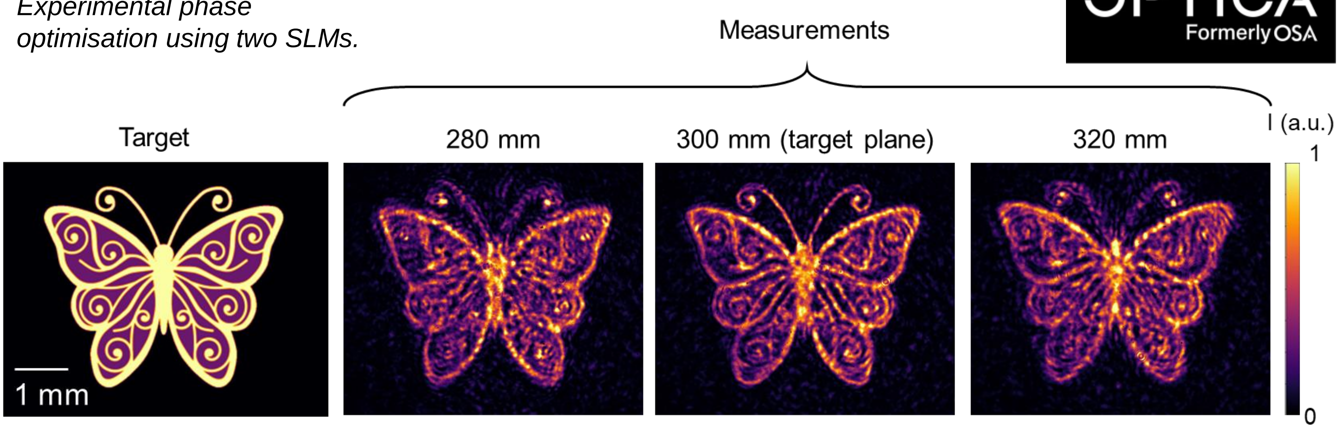
- Prize-winning RWTH beam shaping using SLMs
- Methods for the system synchronisation needed for real-time monitoring and control by fentISS
- Micro-machining results from ILT
- An update on the data pre-processing required for machine learning development at UPV.

More information is available on the project website https://metamorpha.eu

Prize for METAMORPHA beam shaping work

Congratulations to Paul Buske (RWTH) for winning the Best Student Paper Award at the Optica International Optical Design Conference (IODC 2023) held in Québec City (Canada) earlier this summer. His paper was titled *Diffractive Neural Networks Built from Spatial Light Modulators for Laser Beam Shaping in the NIR and VIS.* This novel approach will be instrumental in beam shaping using cascaded SLMs in METAMORPHA.

Experimental phase optimisation using two SLMs.



Consortium

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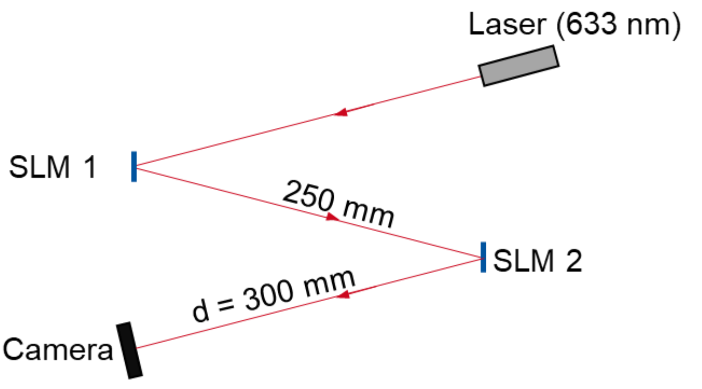
The results shown on the previous page were achieved with the experimental set-up shown on the right. The objective was to demonstrate beam shaping with two cascaded SLMs in a low-power set-up. Conceptually, the set-up is treated as a diffractive neural network which is trained to achieve a butterfly intensity distribution.

Additionally, the set-up is optimised to achieve a constant phase in the target plane for higher depth-of-field. On the previous page, the intensity distributions are shown at the target plane and 20 mm before and behind it. At all distances the butterfly distribution pattern can be recognised, demonstrating that a large depth-of-field has been achieved.



Schematic of the experimental set-up to achieve phase optimisation using two SLMs; the butterfly image results are shown on the previous page.

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METAMORPHA real-time monitoring and control

METAMORPHA requires sophisticated scheduling and communication between the various high speed sub-systems in the machine in order to achieve real-time monitoring and control. fentISS has selected LithOS to facilitate this task. LithOS is a real-time operating system providing support to allow different tasks to be performed in a concurrent way. It also facilitates interactions between hardware and software components by managing devices and handling interrupts. This operating system is inspired by the ARINC-653 IMA standard which is used extensively on avionic systems.

LithOS provides the following external interfaces to its applications:

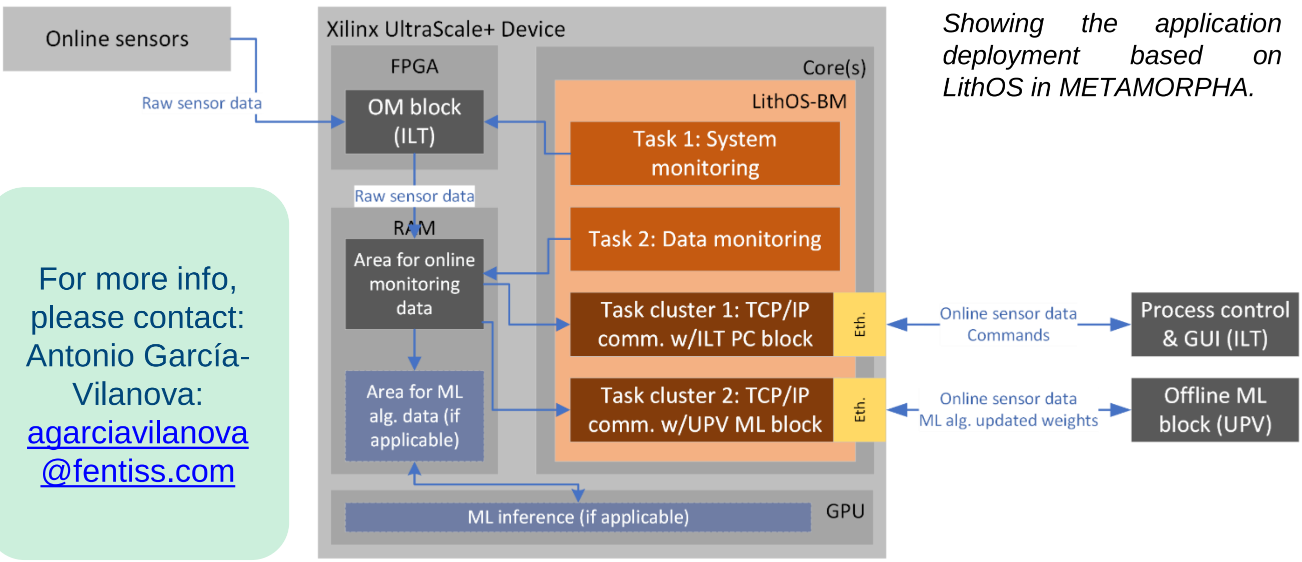
- Time management
- Process management
- Health monitor management: Error notification and mitigation if a fault is detected.
- Intra-partition communication: Inter-process communication mechanisms
    - *I.e.* buffers, blackboards, semaphores and events)
- Partition management
- Interrupt request (IRQ) handling
- Additional services: Implementation-specific tailored services.

During the METAMORPHA project, the following activities are planned regarding the development of the LithOS system:

• BSP adaptation: Adaptation of the Board Support Package (BSP) to support the Xilinx Zynq UltraScale+ EG MPSoC-based boards. Such hardware technology was chosen in the context of previous tasks linked to the METAMORPHA use cases.

• Bare-metal porting: Previous LithOS products were developed to be used with a hypervisor (such as XtratuM) as an intermediate layer within the OS and the hardware. The

LithOS architecture defined in METAMORPHA considers replacing the hypervisor layer by a direct interaction of the OS with the MPSoC components, such as clocks, timers or the IRQ controller.

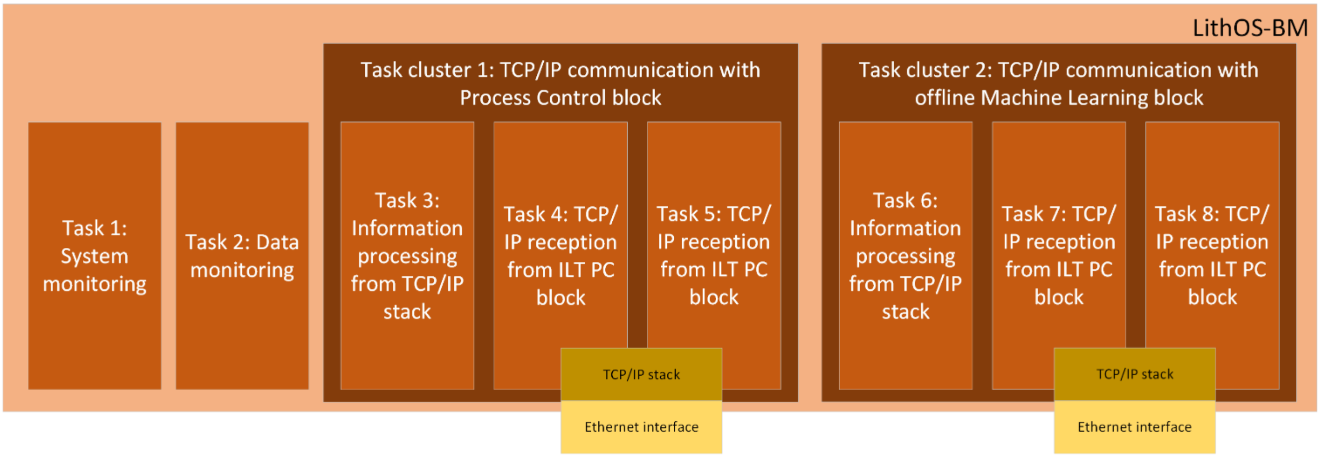


Showing the application deployment based on LithOS in METAMORPHA.

For more info, please contact: Antonio García-Vilanova: agarciavilanova@fentiss.com

The real-time application to be implemented in the context of METAMOPRHA runs an application software (AppSw) which makes use of LithOS as the operating system on a Xilinx UltraScale+ device running on one or several of its CPU cores. The AppSw carries out several METAMORPHA real-time monitoring and data exchanging tasks, which are implemented as periodic and aperiodic LithOS processes. This AppSw yields several responsibilities to LithOS:

- Task scheduling and management according to the appropriate policy
- Communication of any type between tasks
- Time management
- Interrupt management.



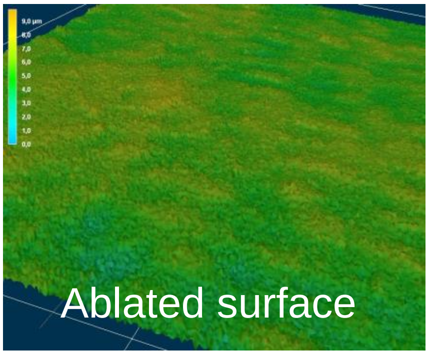
Showing the LithOS task breakdown in the planned METAMORPHA implementation.

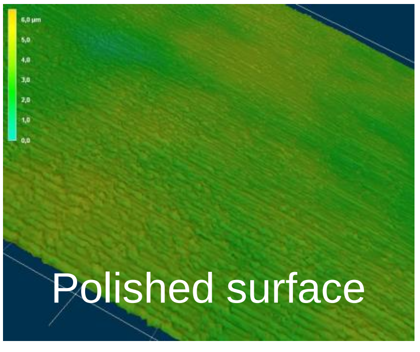
Early micro-machining results at ILT for METAMORPHA use cases

Ceratizit use case: carbide material

In the previous newsletter (#1 Apr-2023) we reported on some first results relating to the Ceratizit use case, involving the laser machining of very hard carbide materials. ILT can now present some more detailed information on the ablation and polishing of this difficult material:

- USP-ablated surface (see image right)
  - Micro roughness (λ < 10 µm): 0.15 ± 0.02 µm
  - Meso roughness (10 µm < λ < 80 µm): 0.28 ± 0.02 µm



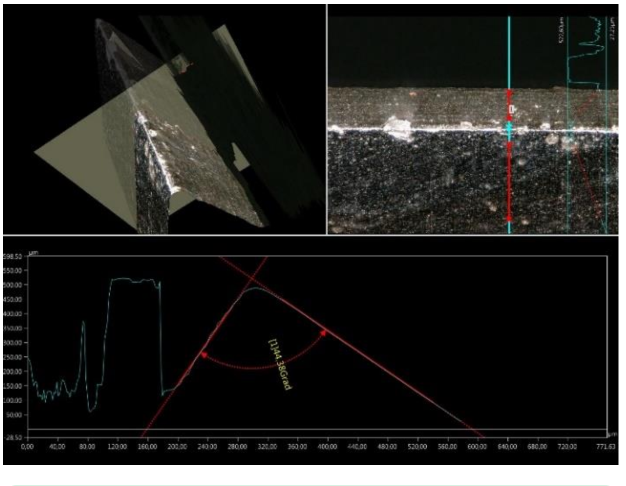


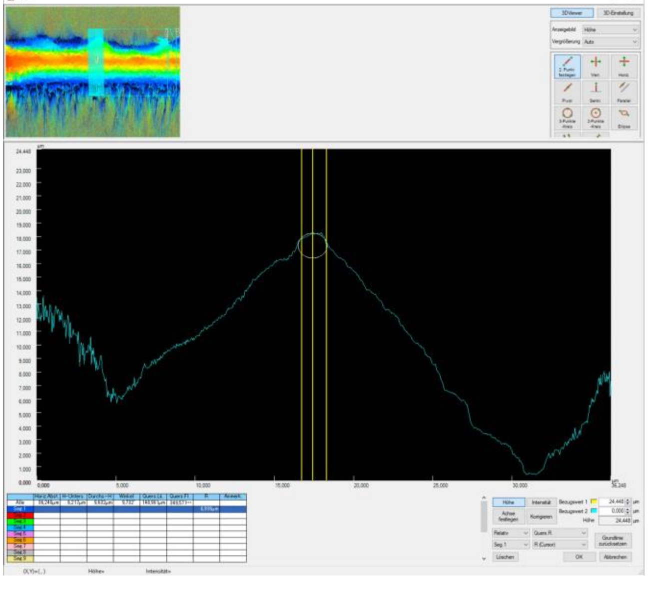
- USP-polished surface (see image left)
  - Micro roughness (λ < 10 µm): 0.11 ± 0.02 µm
  - Meso roughness (10 µm < λ < 80 µm): 0.16 ± 0.02 µm
  - Reduction of micro roughness 27 %
  - Reduction of meso roughness 43 %.

Philips use case: stainless steel

- Stainless steel, 300 µm thick
- 45° chamfer ablation
- 5 mm width
- 0.9 µm edge rounding achieved.

These three images show micrographs and screen shots recording the 45° chamfer angle and rounding as per the target specification.





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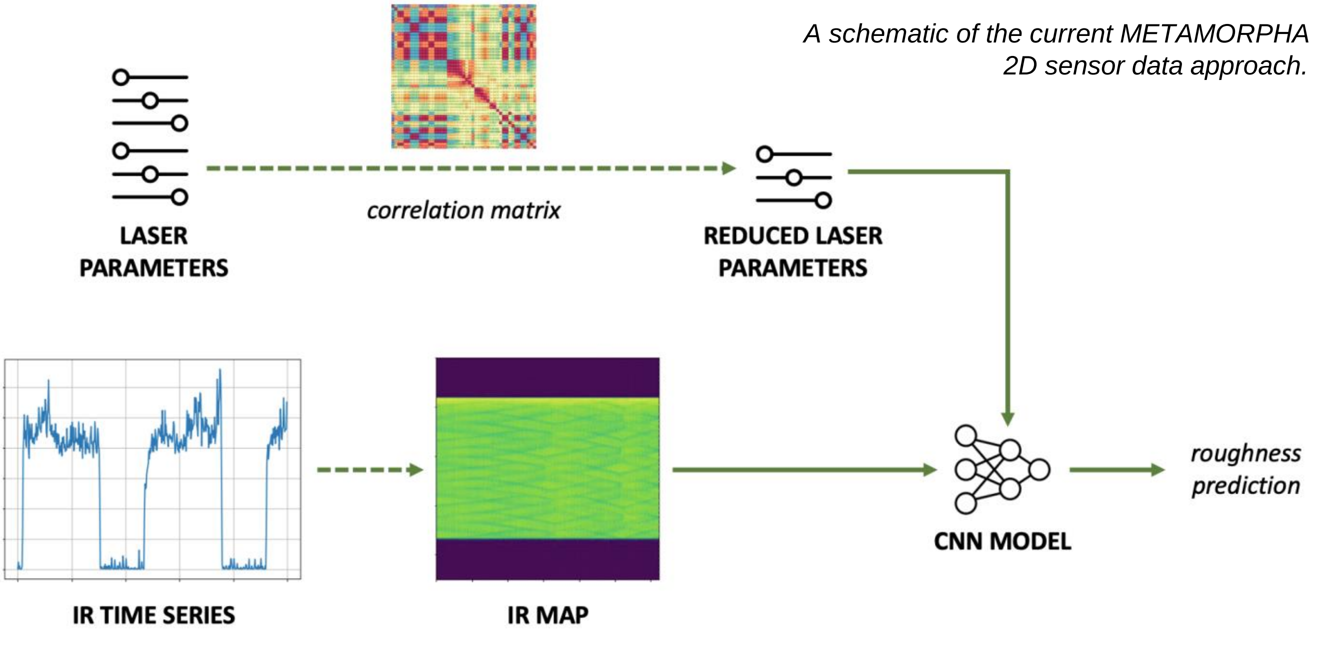
Machine learning for METAMORPHA at UPV

One of the key technologies underlying of the METAMORPHA approach is the use of machine learning (ML) algorithms for dynamic laser process optimisation in real time. By applying these algorithms, the project can advance towards its goals of reducing product waste and elevating laser process efficiency. These ML algorithms are aimed to be directly applied to data captured from various sensors, tailored for 2D sensor data and the 3D point clouds of the workpieces.

Before developing any ML model, a proper pre-processing of data is crucial. This process involves a range of techniques to refine and prepare the raw data and to transform it into the appropriate format to be fed into the ML models. In this context, UPV leveraged laser parameters and 2D sensor data, including infrared and ultraviolet emissions provided by ILT, as well as 3D point clouds from with workpieces, detailing micro-machined surfaces, such as the metal rollers from tkSE. The general approach is sketched in the figure below.

A schematic of the current METAMORPHA 2D sensor data approach.



Throughout these initial project months, UPV has focused on the meticulous analysis and pre-processing of the distinct input data. This included tasks such as identifying appropriate Python libraries for handling 3D point clouds efficiently, filtering out irrelevant laser parameters, and translating sensor time series into 2D maps that represent the different sensor emissions at each laser position. With the data properly pre-processed, UPV is now working on the first ML approach with a specific emphasis on the 2D sensor data. The primary objective of this work is to predict the workpiece surface roughness by utilising convolutional neural networks (CNN), leveraging both the newly generated maps and their associated laser parameters as inputs.

UPV will report on progress in future newsletters, so please sign up for the mailing list!

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